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(54) METHODE DE REGENERATION DE MATERIAUX ABSORBANTS
(54) METHOD FOR THE REGENERATION OF SORBENT MATERIALS

(57)
The process of the present invention is directed to the use of sulfuric acid and/or an organic acid to regenerate spent sorbent from a metal recovery process. The sorbent can be activated carbon.



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ABSTRACT

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METHOD FOR THE REGENERATION OF SORBENT MATERIALS

CROSS-REFERENCE TO RELATED APPLICATION

The present application is a continuation-in-part of U.S. Patent Application entitled
5 "Method for the Regeneration of Activated Carbon" having Serial No. 09/454,584, filed
December 6, 1999, which is incorporated herein by reference.

FIELD OF THE INVENTION

The invention relates generally to the regeneration of sorbents used for metal removal and
specifically to the regeneration of carbonaceous sorbents.

10 BACKGROUND OF THE INVENTION

Cyanidation is commonly employed for the extraction of gold from its ores. In this
process, the crushed ore is treated with a dilute solution of sodium cyanide (NaCN), and a small
amount of lime (CaO) to maintain a pulp pH of >9 . In the presence of oxygen, gold dissolves
forming gold cyanide complex.

15 Recovery of the gold is typically accomplished by adsorbing the gold cyanide complex
on activated carbon. The gold-loaded carbon is subjected to an elution process whereby the gold
is eluted from the carbon by an eluant. The eluted (spent) carbon contains a low concentration
of gold and has its gold adsorption capacity reduced. The spent carbon must therefore be
regenerated before reuse.

20 Various regeneration methods have been proposed and practiced, but all of the methods
are problematical in the areas of cost, regeneration efficiency and maintenance of the mechanical
strength of the regenerated carbon. Therefore, development of an effective and economical
regeneration method has been eagerly desired in the art.

Some conventional methods for the regeneration of activated carbon are: (a) a low
25 temperature heating method comprising heating spent carbon at a temperature of 100-400°C.
with steam or the like, (b) a high temperature heating method comprising heating spent carbon
at a temperature of 400-1000°C., (c) a regeneration method using a high temperature inert gas,
(d) a chemical regeneration method using acid or alkali, and (e) a wet oxidation method, etc.

In the gold mining industry using Carbon-in-Pulp (CIP) or Carbon-in-Leach (CIL) process, good carbon activity is important. Each mining operation has to match carbon activity with process requirements. When thermal carbon regeneration is used to regenerate spent carbon, it is a general rule that the higher the carbon activity the weaker the carbon and thus higher carbon losses in these processes. Therefore, it is common practice in the industry to thermally regenerate 50% or less of the total process carbon to save on regeneration costs and to reduce carbon losses.

Chemical methods of regenerating carbon achieve partial regeneration of the carbon and can reduce the frequency of thermal regeneration. It is employed to remove specific solvents and/or compounds from the carbon. The most common of the chemical methods are; (a) acid washing the spent carbon with hydrochloric or nitric acid solutions, and (b) caustic washing with sodium hydroxide solution to remove organic contaminants.

Acid washing using nitric or hydrochloric acid at room temperature after elution may restore carbon activity to some extent, but the improved carbon activity is small compared with that of thermal regeneration.

Carbon activation with sulfuric acid by impregnation and heating at 250°C for 4-6 hours was reported to improve adsorption of ammonia by active carbon fibers.

Davidson et al., U.S. Pat. No. 4,267,069, tried to increase carbon gold adsorption capacity by contacting the carbon with an aqueous copper salt solution at a pH less than 6 in the presence of carbonic acid, carbonate or bicarbonate.

Hanceford et al., U. S. Patent No. 4,407,725, tried to regenerate activated carbon with caustic wash and an optional periodic acid wash.

Lambert et al., U. S. Patent No. 5,087,374, tried to regenerate activated carbon used to purify wastewater with an aqueous bath containing a surface-active agent while ultrasonic vibration is applied to the aqueous bath.

Activated carbon used for liquid phase, however, cannot be regenerated unless it is subjected to the high temperature heating method, namely, a re-activation or a thermal regeneration method in which regeneration is effected under the same conditions as adopted for production of activated carbon. Further, regeneration conditions, such as the amount of steam

and the residence time in the regenerating furnace vary depending on amount and properties of activated carbons. Therefore, regeneration loss is increased by prolongation of the residence time, excessive incorporation of air and the like, and simultaneously, the mechanical strength is reduced in the regenerated activated carbon.

Furthermore, in some cases the exhaust gas from the regenerating furnace causes secondary air pollution. On the other hand, the chemical regeneration method in which high temperature heating is not conducted is advantageous in that the regeneration loss can be reduced, but the degree of regeneration is insufficient and lower than in the thermal regeneration method and both the waste coming from the spent carbon and the chemicals used for regeneration should be treated completely.

In summary, prior methods of regenerating activated carbon had disadvantages including the following:

- high energy costs of thermal regeneration;
- weakened carbon and generation of carbon fines;
- inadequate regeneration;
- expensive reagents;
- complex process; or
- expensive equipment.

Accordingly, the development of a regeneration method that will be able to overcome these defects involved in the conventional methods and to perform regeneration at an optimum regeneration rate with lessened regeneration loss has been highly demanded in the art.

As a result of intensive investigation made on regeneration of activated carbon, a novel activated carbon regeneration process has been discovered that satisfies the above-mentioned demands held in the art.

SUMMARY OF THE INVENTION

These and other needs are addressed by the process of the present invention. Generally, the present invention provides a methodology for regenerating a sorbent, such as activated carbon, for reuse in a metal adsorption, absorption, or entrapment process. As used herein, a

"sorbent" refers to any substance that absorbs, adsorbs, or entraps another material. The methodology utilizes an organic acid and/or sulfuric acid during sorbent regeneration.

In one embodiment, the process includes the following steps:

- (a) leaching (such as with a lixiviant) a metal-containing material to form a pregnant
5 leach solution containing at least a portion of the metal,
- (b) contacting the pregnant leach solution with a sorbent to form a loaded sorbent
containing at least a portion of the metal dissolved in the pregnant leach solution,
- (c) contacting the loaded sorbent with an eluant to form a loaded eluant containing
at least a portion of the metal in or on the loaded sorbent and a spent sorbent,
- 10 (d) contacting the spent sorbent with an organic acid to form a regenerated sorbent,
and
- (e) recovering the metal from the loaded eluant.

The process is effective for a variety of metals and metal complexes. Preferably, the metal is a member of any one of Groups VIIIA, IB, or IIB, of the Periodic Table of the Elements.
15 More preferably, the metal is gold, silver, platinum, copper, nickel, cobalt, mercury, and/or mixtures thereof. The metal can be complexed when in the pregnant leach solution, eluant, and/or in or on the loaded sorbent, with a variety of functional groups, including cyanide, thiocyanate, thiosulphate, and mixtures thereof. Typically, the metal is complexed with cyanide.

The lixiviant in step (a) can be any suitable material for dissolving the metal in the metal-
20 containing material. Preferably, the lixiviant is one or more of cyanide, thiosulfate, thiourea, thiocyanate, and mixtures thereof. The leaching step can be performed by contacting the lixiviant with the material in a stirred or agitated or unstirred or unagitated vessel such as an open vessel or a closed vessel such as an autoclave or by applying the lixiviant to a pile or heap of the material or by applying the lixiviant to the material in situ.

25 The pregnant leach solution is contacted with the sorbent in any suitable vessel by any suitable technique. Preferably, the pregnant leach solution is contacted with the sorbent in an open or closed stirred or agitated or unstirred or unagitated vessel or by passing the pregnant leach solution through a bed of the sorbent in either a fluidized or fixed bed configuration.

The sorbent can be any suitable material for absorbing, adsorbing, or otherwise entrapping the metal. Preferably, the sorbent is organic and more preferably the sorbent is carbon (e.g., activated carbon), resins, and/or mixtures thereof.

As in the case of the pregnant leach solution, the eluant can be contacted with the loaded sorbent in any suitable vessel by any suitable technique. Preferably, the pregnant leach solution is contacted with the sorbent in a stirred or agitated or unstirred or unagitated vessel or by passing the pregnant leach solution through a bed of the sorbent in either a fluidized or fixed bed configuration.

The eluant can include any suitable eluting materials, such as ammonia, carbohydrates (a compound having the formula $C_x(H_2O)_y$ where x and y are whole numbers), inert gases such as molecular nitrogen, a metal hydroxide (a compound containing one or more OH^- groups), cyanides (a compound containing one or more $-CN$ radicals), alcohols (an organic compound containing one or more hydroxyl groups), ketones (a compound in which the carbonyl group is attached to two alkyl groups), nitriles (an organic compound containing the $-C\equiv N$ grouping), acetone, cyanates (a salt of cyanic acid containing the radical $-CNO$), hydrazines, hydroxy acids, carboxylic acids, hydrocarbons (a compound consisting only of C and H), and mixtures thereof. The eluant typically includes a solvent for the eluting material. To avoid competing with the eluting material in displacement of the metal or metal complex from the sorbent, the solvent in a preferred embodiment preferably is a polar or substantially polar compound and the eluting material is nonpolar or substantially nonpolar. Preferred solvents include water, alcohols, and mixtures thereof. The preferred elution process is described in U.S. Patent Application Serial No. 09/372,025, filed August 13, 1999, and Serial No. 09/632,386, filed August 3, 2000, both of which are incorporated herein by this reference.

The regeneration of the spent sorbent is preferably performed using an inorganic acid such as a mineral acid (e.g., sulfuric acid) and/or an organic acid such as a hydroxy acid (e.g., an acid containing one or more hydroxy groups such as glycolic acid and/or lactic acid) and/or a carboxylic acid (e.g., an acid containing one or more carboxylic groups such as acetic acid (or methanecarboxylic acid), formic acid, caproic acid, oxalic acid, cerotic acid, aromatic acids such as benzoic acid and salicylic acid, alicyclic acids such as abietic acid and chaulmoogric acid

and/or amino acids), with organic acids particularly hydroxy acids being preferred and hydroxycarboxylic acids (particularly glycolic acid) being even more preferred. The operating parameters for the regeneration are important to realize the optimum degree of regeneration. The pH at which the regeneration is performed typically ranges from about pH 0.5 to about pH 3 and the temperature typically from about ambient to about 95°C. The concentration of the acid in the regeneration or acid wash solution contacted with the spent sorbent preferably ranges from about 3 to about 10 % weight. Regeneration can be performed in any suitable stirred or unstirred, agitated or unagitated vessel or by passing the acid wash solution through the spent sorbent in a fluidized or fixed bed configuration with the latter being preferred.

While not wishing to be bound by any theory, it is believed that the shorter chain organic acids, particularly glycolic acid, penetrate deeply into the sorbent matrix, particularly for organic sorbents such as carbonaceous sorbents. The depth of acid penetration into the matrix is believed to be dependent upon factors such as the shape of the acid molecule and the charge distribution on the molecule. The deep penetration of the acid inhibits removal and/or neutralization of the acid when the sorbent is water rinsed (after the regenerative acid wash) to remove excess acid. Unremoved (excess) acid will consume cyanide and other basic leaching agents when the sorbent is again contacted with the pregnant leach solution. During the contacting step (b) above, the unremoved acid in the sorbent matrix is believed to cause a lower pH to exist in or near the sorbent surface and/or pores than exists in the surrounding pregnant leach solution. The lower pH causes the metal to be more strongly attracted to the sorbent, thereby causing a higher amount of metal collection in the sorbent than has been previously realized with acids such as nitric acid and hydrochloric acid, which are not believed to penetrate deeply into the sorbent matrix. Organic sorbents such as activated carbon are believed to adsorb organic acids better than inorganic acids such as nitric acid and hydrochloric acid.

In one configuration that is particularly applicable to carbon-containing sorbents, a first portion of the spent carbon is contacted with the organic acid and a second portion of the spent carbon is contacted with sulfuric acid. The first portion of the spent carbon is subsequently thermally reactivated (*e.g.*, in a kiln or other suitable reactor or heater typically at a temperature ranging from about 600 to about 800°C) before being recycled to step (b) above and the second

portion is not subsequently thermally reactivated before being recycled to step (c) above. The presence of an excessive amount of the sulfur atom in or on the second portion may cause oxidation and loss of carbon from carbon-containing sorbents during thermal reactivation.

The regenerated sorbent will typically contain some of the acid on the surface of or inside the pores of the sorbent. For example, regenerated carbon typically includes sulfuric acid and/or the organic acid adsorbed in a plurality of pores of the carbon.

The process, in one or more of its many embodiments, can have a number of advantages. Treating the activated carbon with a solution containing organic acids, particularly glycolic acid, can restore significant gold adsorption capacity to the spent sorbent. The process can have low capital and operating costs yet high regeneration efficiency and can maintain the mechanical strength of the regenerated sorbent. Although the process uses thermal reactivation techniques in one embodiment, other embodiments employ no thermal reactivation and are conducted at ambient to below about 100° temperatures, which lowers operating (energy) costs, is energy efficient, and avoids compromising the structural integrity of the carbon (thereby generating few if any carbon fines and reducing loss of carbon). Even when thermal reactivation is employed, the spent sorbent is typically heated to relatively low temperatures, which will not seriously compromise the mechanical strength of the regenerated sorbent. The regeneration techniques of the present invention can be fast and highly effective, thereby decreasing the risk of inadequate regeneration. The process can use relatively inexpensive reagents such as sulfuric acid and glycolic acid at optimum regeneration rates. The process can be relatively simple and can use relatively inexpensive equipment. In some embodiments, the regeneration process is performed *in situ*, thereby requiring less carbon handling. The process can be readily adapted to existing plants and infrastructures. The description and drawings below show additional objects and advantages.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows the major components and flow directions of a typical elution process incorporating the chemical regeneration process of the eluted (spent) carbon.

FIG. 2 shows another embodiment of a regeneration process that may be employed with any suitable elution process;

FIG. 3 shows the plot of gold adsorption rate of carbons subjected to different carbon regeneration treatment.

5 FIG. 4 shows carbons that have been subjected to further gold adsorption cycles to increase its gold loading capacity.

DETAILED DESCRIPTION

General Discussion

10 Although the process embodiments discussed below specifically refer to the elution of gold from gold-loaded activated carbon generated from an extractive metallurgical process using a cyanide-containing lixiviant and a carbohydrate-containing eluant, it is to be understood that the processes are equally applicable for metals other than gold for eluants that do not contain carbohydrates, and for processes other than extractive metallurgy. For example, the processes can be used on other precious metals and base metals, to name but a few, and may be used to
15 elute or remove metals/metal complexes from sorbents generated in water treatment and/or purification processes.

 The acid wash solution can include any suitable mineral acid, such as nitric acid, hydrochloric acid, sulfuric acid, and/or an organic acid such as glycolic acid, and preferably has a pH ranging from about pH 0.1 to about pH 5 and more preferably from about pH 0.5 to about
20 pH 2. The concentration of the acid in the acid wash solution preferably arranges from about 0.5 to about 25 vol.% and more preferably from about 3 to about 5 vol%.

 While not wishing to be bound by any theory, it is believed that the eluting or blinding agent, in the presence of the acidic pH, is at most only weakly attracted to the sorbent, thereby causing a large fraction (typically at least about 90%) of the blinding agent into the solution from
25 the sorbent surface. In other words, in the presence of a basic pH, the equilibrium between the blinding agent in the solution and the blinding agent on the surface of the sorbent strongly favors the attachment of the blinding agent to the sorbent surface. In contrast in the presence of an

acidic pH, the equilibrium between the dissolved blinding agent and the blinding agent on the surface of the sorbent strongly favors the dissolution (or hydrolysis) of the blinding agent.

The temperature of the acid wash typically ranges from about 80 to about 120°C.

After the solvent has been contacted with the acid wash for a time typically ranging from
5 about 1 to about 2 hours, the regenerated sorbent can be rinsed with water to remove residual acid solution.

The sorbent can then be reused in a variety of known processes to remove dissolved metal/metal complexes from pregnant lixiviant solutions, industrial effluents, waste waters, etc., to form metal/metal complex loaded sorbent for use as the feed material in any elution processes
10 including those described above.

Preferred Embodiment -- Description

A preferred process involving selected major operations is shown in FIG. 1. The gold-loaded carbon is soaked in the carbon elution column 10 at a temperature preferably ranging from about 80 to about 100°C and more preferably about 95°C with an organic acid wash
15 solution 14 (having about 2% w/w organic acid) typically for at least about one hour. The acid wash solution 14 is drained out of the carbon column 10 and the carbon is thereafter neutralized with a suitable base 18 such as ammonia water (having about 2% w/w base) by passing the base 18 through the column 10. The gold-loaded carbon is then eluted in the column 10 with an eluant 22 in column 10 to strip the gold from the carbon and form gold-loaded eluant 26. After
20 the elution process, the spent carbon in column 10 is washed with hot (e.g., about 95°C) acid wash solution 30. As will be appreciated, the organic acid wash solutions 14, 30 can be stored in the same vessel or in separate vessels. Heater 34 and heat exchanger 38 are used to heat the various solutions as desired.

The reagents used in this process, e.g., glycolic acid and ammonia solutions, may be
25 reused if necessary by draining each solution back to their respective holding tank after each batch of carbon is treated by the solution. The solution can be made up to strength with fresh reagents before reuse.

The pre-elution treatment using organic acid solution 14 and base 18 hastens the elution process as well as helps in the regeneration of the spent carbon in the post-elution treatment with organic acid solution 30.

Preferred Embodiment -- Operation

5 This part describes how my invention operates in reference to FIG. 1.

As indicated in FIG. 1, the gold-loaded carbon in column 10 is prepared for elution by washing with about 1.5 to 2 Bed Volumes (BV) of about 2% weight by weight ratio (w/w) organic acid wash solution 14 at about 95°C for one hour. The organic acid solution 14 is drained and the carbon is neutralized in column 10 with about 1.5 to 2 BV of 2% w/w base or
10 basic solution 18 for another hour. This pre-elution treatment is meant to: (a) dissolve carbonate scale and reduce levels of calcium, magnesium, aluminum, and other metals, (b) reduce overall contaminant levels in the pores of the carbon, (c) hasten the elution process, and (d) help in the chemical regeneration of the carbon.

Eluant 22 is then contacted with the loaded carbon in column 10 to form the gold-loaded
15 eluant 26. After the elution is at least substantially completed, the eluant 22 is drained from the carbon column 10. The spent carbon is then soaked in column 10 with about 2% w/w organic acid solution 30 at about 95°C to regenerate the spent carbon. The acid wash treatment is repeated at about 1.5 to 2 BV per hour for at least about one hour. The organic acid solution 30 is then drained from column 10 for reuse.

20 Alternative Embodiment

In-Situ Regeneration of Carbon-- Description

An additional embodiment conducts the alternating process of metal (e.g., gold) adsorption onto the sorbent and organic acid or sulfuric acid washing on the organic sorbent (e.g., carbon) to increase its metal loading capacity.

25 This embodiment relates to the regeneration of the organic sorbent outside of the elution process to increase gold loading capacity.

In-Situ Regeneration of Carbon -- Operation

In the process of recovering the metal (particularly gold) from a pregnant leach solution (particularly a cyanide solution) using an organic sorbent or sulfuric acid (particularly activated carbon), the loading capacity of the sorbent carbon can be increased by the alternating process of metal adsorption and organic acid washing.

In one configuration, the operation involves the following steps:

- Drain the gold cyanide solution from the carbon column 10 after at least a portion of the gold (or other metal) is loaded onto the carbon;
- Rinse the gold loaded carbon with water to reduce the cyanide concentrations on the carbon;
- Drain the rinse water from the column 10 and soak the carbon in the organic acid solution in column 10;
- Drain the organic acid or sulfuric acid solution from column 10 and rinse with at least about one bed volume of water to reduce acidity; and
- Put the carbon column into operation (e.g., proceed with eluting the gold from the carbon and/or regenerating the sorbent).

The process can be done in any carbon vessels and at any temperatures. The organic or sulfuric acids and basic solutions preferably use the concentrations noted above. As will be appreciated, the process can be used for other metals and other sorbents described herein.

As will be appreciated, higher acid washing temperatures will achieve faster carbon regeneration.

In another embodiment of the present invention both a first acid wash solution containing an organic acid and a second acid wash solution containing an inorganic acid or a first acid wash solution containing a first organic acid and a second acid wash solution containing a second organic acid different from the first organic acid are employed to acid wash first and second portions, respectively, of the spent sorbent. One or both of the separately washed portions can be further subjected thermal reactivation to provide a high degree of sorbent activity.

In another embodiment of the present invention, glycolic acid, sulfuric acid, or both, is used to reactivate spent sorbent that may or may not undergo thermal regeneration before reuse.

FIG. 2 shows this process according to this embodiment when the spent sorbent is generated using a less common continuous elution process. Most spent carbon is produced batchwise using a batch elution process; therefore the alternating batches of spent sorbent are thermally reactivated or not thermally reactivated. To further save on cost, spent sorbent that will be thermally regenerated is typically not acid washed. In this configuration, only spent sorbent that will not be thermally regenerated is acid washed with glycolic or sulfuric acid by a hot, preferably acid wash.

Referring to FIG. 2, the spent sorbent 100 in the embodiment using continuous elution is first divided 104 into separate first and second portions 108, 112 by any suitable technique and in any proportion. The first portion 108 is subjected to a first acid wash 116 using a first acid wash solution 120 containing an organic acid such as glycolic acid to form an acid washed first portion 124. The acid washed first portion 124 is then thermally reactivated 128 typically at a temperature ranging from about 600 to about 800°C in a suitable reactor or heater for a time ranging from about 30 to about 60 min. to form thermally reactivated first portion 132. The second portion 112 is acid washed 136 with a second acid wash solution 140 containing an inorganic acid such as sulfuric acid to form acid washed second portion 144. The acid washed second portion 144 and thermally reactivated first portion 132 are recombined 148 by suitable techniques to form the regenerated sorbent 152, which may be reused in the sorption/elution process.

As noted, Fig. 2 reflects a process utilizing the continuous elution of spent sorbent. For a batchwise process, Fig. 2 would be modified such that alternating batches of eluted or spent sorbent would constitute the first and second portions 108, 112. The dividing step 104 and recombining step 148 would be absent from the flow schematic in this embodiment as the first and second portions would be discrete from each other. As will be appreciated, when alternating batches of spent sorbent 100 are regenerated sequentially, a separating or dividing step would not be utilized. As noted, the first portion 108 may not be acid washed before thermal reactivation to reduce costs, and the first portion 108 and second portion 112 are sequentially and alternative respectively thermally reactivated and not thermally reactivated.

Example 1

A method for comparing carbon activity was used to compare the following carbon regeneration treatments:

- Spent carbon, with no regeneration treatment;
- 5 • Spent carbon, acid washed at 95°C with nitric acid (HNO₃);
- Spent carbon, acid washed at 95°C with hydrochloric acid (HCl);
- Spent carbon, acid washed at 95°C with glycolic acid (GA); and
- Spent carbon, with thermal regeneration.

Methodology involves presoaking one gram of carbon sample in "tailings" slurry for one
 10 hour before adding the carbon to one liter of standard gold cyanide solution containing about 10
 ppm gold and buffered to pH 10. The purpose of presoaking the carbon in tailings slurry was to
 neutralize the "pH effect" of the acid treatment on carbon activity. The carbon samples were
 screened to minus 8-mesh and plus 10-mesh. At 15 minutes time intervals a small aliquots of test
 solution were removed to determine the remaining gold concentration. A plot is prepared for
 15 each carbon sample as shown in FIG. 3.

The data shows no significant improvement in carbon activity was attributed to the use
 of nitric and hydrochloric acid wash. Conventional acid washing allows for the removal of
 minerals containing calcium, magnesium and aluminum. The removal of these minerals proves
 helpful in improving thermal regeneration of the carbon.

20 On the other hand, washing with glycolic and sulfuric acid solution, significantly
 improved carbon activity. It is possible that thermal regeneration can be significantly reduced or
 eliminated in gold-adsorption processes such as CIL or CIP.

Maximum carbon regeneration was achieved by thermal regeneration at a price of high
 carbon losses. It is not always necessary to have a carbon that has very high activity. The gold
 25 adsorption process will dictate the required carbon activity for optimum operation.

Example 2

FIG. 4 and Table 1 show that alternating gold adsorption and glycolic acid washing of
 the loaded carbon can increase the gold loading capacity of the carbon. Two spent carbons, A

and B, each initially containing 300-ppm gold were subjected further to four periods of gold adsorption. Carbon A was not acid washed between periods while Carbon B was acid washed with glycolic acid and water rinsed between periods.

5 The methodology involves two grams of carbon sample added to 100 mL of 127 ppm gold solution. The gold solution contains 0.5 g/L sodium cyanide and 1 g/L calcium hydroxide. The gold adsorption period was 2 hours and the acid washing period was 15 minutes with water rinse. After each gold adsorption period the gold solution was analyzed to determine the amount of gold adsorbed by the carbon. The carbon was then put into fresh gold solution for the next gold adsorption period.

10

Table 1

	Gold loading (ppm gold) in the Carbon after each cycle			
Cycles	1	2	3	4
Carbon A	3820	6010	7615	9135
Carbon B	3990	7635	10785	13530

15 While various embodiments of the present invention have been described in detail, it is apparent that further modifications and adaptations of the invention will occur to those skilled in the art. However, it is to be expressly understood that such modifications and adaptations are within the spirit and scope of the present invention.

What is claimed is:

1. A process for recovering a metal from a metal-containing material, comprising:
 - (a) leaching the material to form a pregnant leach solution containing at least a portion of the metal,
 - 5 (b) contacting the pregnant leach solution with a sorbent to form a loaded sorbent containing at least a portion of the metal,
 - (c) contacting the loaded sorbent with an eluant to form a loaded eluant containing at least a portion of the metal in the loaded sorbent and a spent sorbent,
 - (d) contacting the spent sorbent with an organic acid or sulfuric acid to form a
10 regenerated sorbent, and
 - (e) recovering the metal from the loaded eluant.
2. The process of Claim 1, wherein the sorbent is at least one of carbon, and resin.
3. The process of Claim 1, wherein step (a) is performed by contacting a lixiviant with the material and wherein the lixiviant includes at least one of cyanide, thiosulfate, thiourea,
15 thiocyanate and mixtures thereof.
4. The process of Claim 1, wherein the eluant includes at least one of a carbohydrate, a hydroxide, a cyanide, an alcohol, a ketone, a nitrile, acetone, a cyanate, a hydrazine, a hydroxy acid, a carboxylic acid, a hydroxycarboxylic acid, a hydrocarbon, ammonia, and mixtures thereof.
5. The process of Claim 1, wherein the metal is a member of at least one of Groups
20 VIIIA, IB, or IIB of the Periodic Table of the Elements.
6. The process of Claim 1, wherein the organic acid is one or more hydroxy acids.
7. The process of Claim 6, wherein the hydroxy acid is one or more hydroxycarboxylic acids.
8. The process of Claim 1, wherein the regenerated sorbent is reused in step (b).
- 25 9. The regenerated sorbent made in the process of Claim 1.
10. The metal recovered in the process of Claim 1.
11. A process for treating spent carbon, comprising contacting the spent carbon with an organic acid.

12. The process of Claim 11, further comprising:

(a) leaching the material with a lixiviant to form a pregnant leach solution containing at least a portion of the metal,

(b) contacting the pregnant leach solution with a sorbent to form a loaded sorbent containing at least a portion of the metal,

(c) contacting the loaded sorbent with an eluant to form a loaded eluant containing at least a portion of the metal in the loaded sorbent and a spent sorbent, wherein the lixiviant includes at least one of cyanide, thiosulfate, and mixtures thereof, and the eluant includes at least one of a carbohydrate, ammonia, a hydroxide, a cyanide, an alcohol, a ketone, a nitrile, acetone, a cyanate, a hydrazine, a hydroxy acid, a carboxylic acid, a hydroxycarboxylic acid, a hydrocarbon, and mixtures thereof.

13. The process of Claim 11, wherein the metal is a member of at least one of Groups VIIIA, IB, OR IIB of the Periodic Table of the Elements.

14. The process of Claim 11, wherein the organic acid is one or more hydroxy acids.

15. The process of Claim 14, wherein the hydroxy acid is one or more hydroxycarboxylic acids.

16. The process of Claim 15, wherein the hydroxycarboxylic acid is selected from the group consisting essentially of glycolic acid, lactic acid, and mixtures thereof.

17. The process of Claim 12, wherein the regenerated sorbent is reused in step (c).

18. The regenerated sorbent made in the process of Claim 11.

19. The metal recovered in the process of Claim 11.

20. The process of Claim 11, further comprising:

contacting the spent carbon with a metal-containing solution to form a metal loaded carbon;

contacting the metal loaded carbon with at least one of an organic and inorganic acid to form a treated metal loaded carbon; and

contacting the treated metal loaded carbon with an eluant.

21. Regenerated carbon for reuse in an elution process, comprising an organic acid adsorbed in a plurality of pores of the carbon.

22. The regenerated carbon of Claim 21, wherein the organic acid is a hydroxy acid.

23. The regenerated carbon of Claim 22 wherein the hydroxycarboxylic acid is selected from the group consisting of glycolic acid, lactic acid, and mixtures thereof.

24. The regenerated carbon of Claim 22, wherein regenerated carbon includes both the sulfuric acid and the organic acid.

25. The regenerated carbon of Claim 22, wherein the regenerated carbon includes a hydroxycarboxylic acid.

26. A process for eluting a metal from a sorbent, comprising:
contacting a metal-loaded sorbent with an organic acid or sulfuric acid to form a treated metal-loaded carbon; and

contacting the treated metal-loaded carbon with an eluant to form a barren sorbent and a metal-loaded eluant containing at least most of the metal loaded onto the metal-loaded sorbent.

27. The process of Claim 26, wherein the organic acid is a hydroxy acid.

28. The process of Claim 26, wherein the hydroxy acid is selected from the group consisting of glycolic acid, lactic acid, and mixtures thereof.

29. The process of Claim 26, wherein the sorbent is at least one of activated carbon, a resin, and mixtures thereof.

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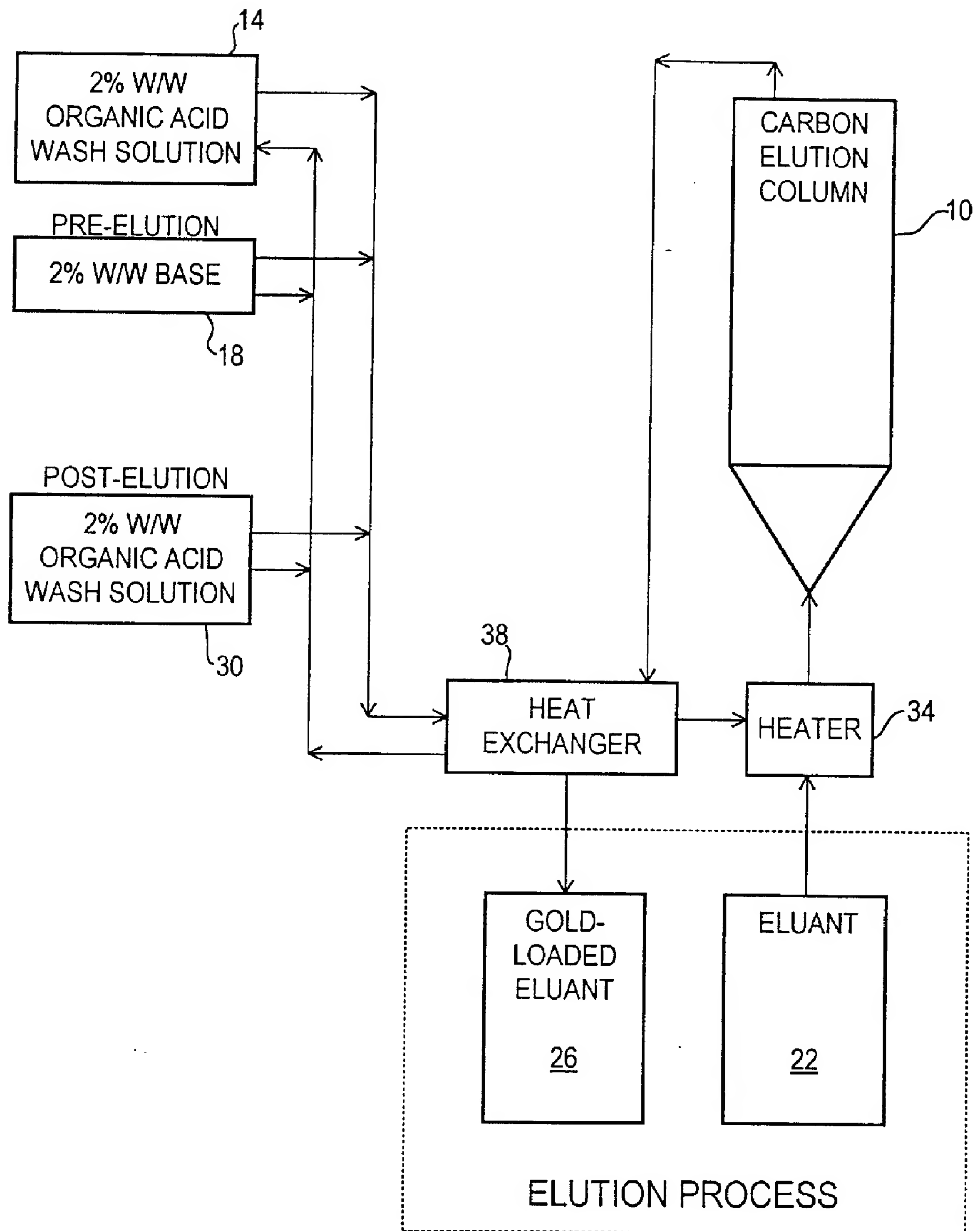


FIG. 1

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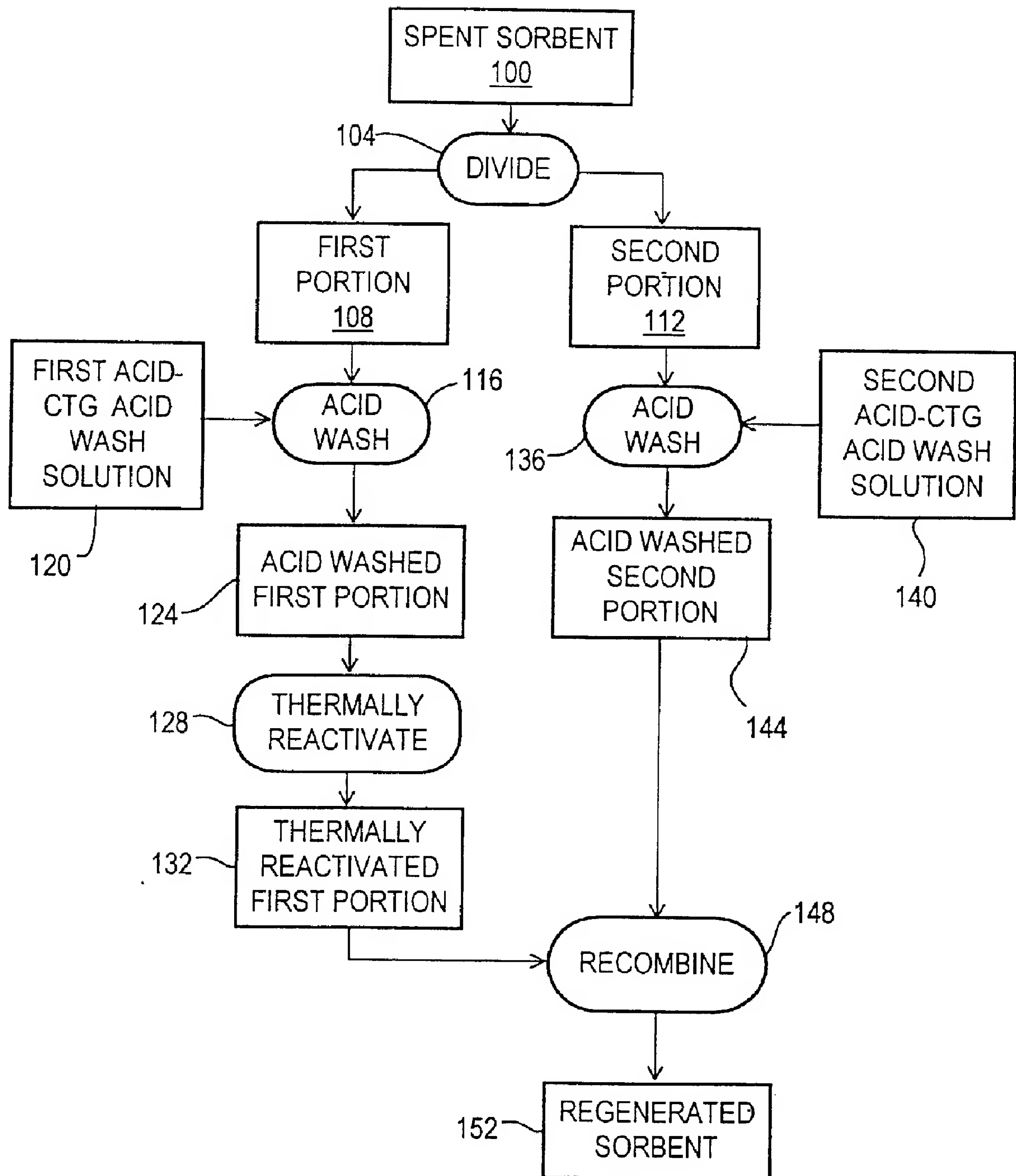


FIG. 2

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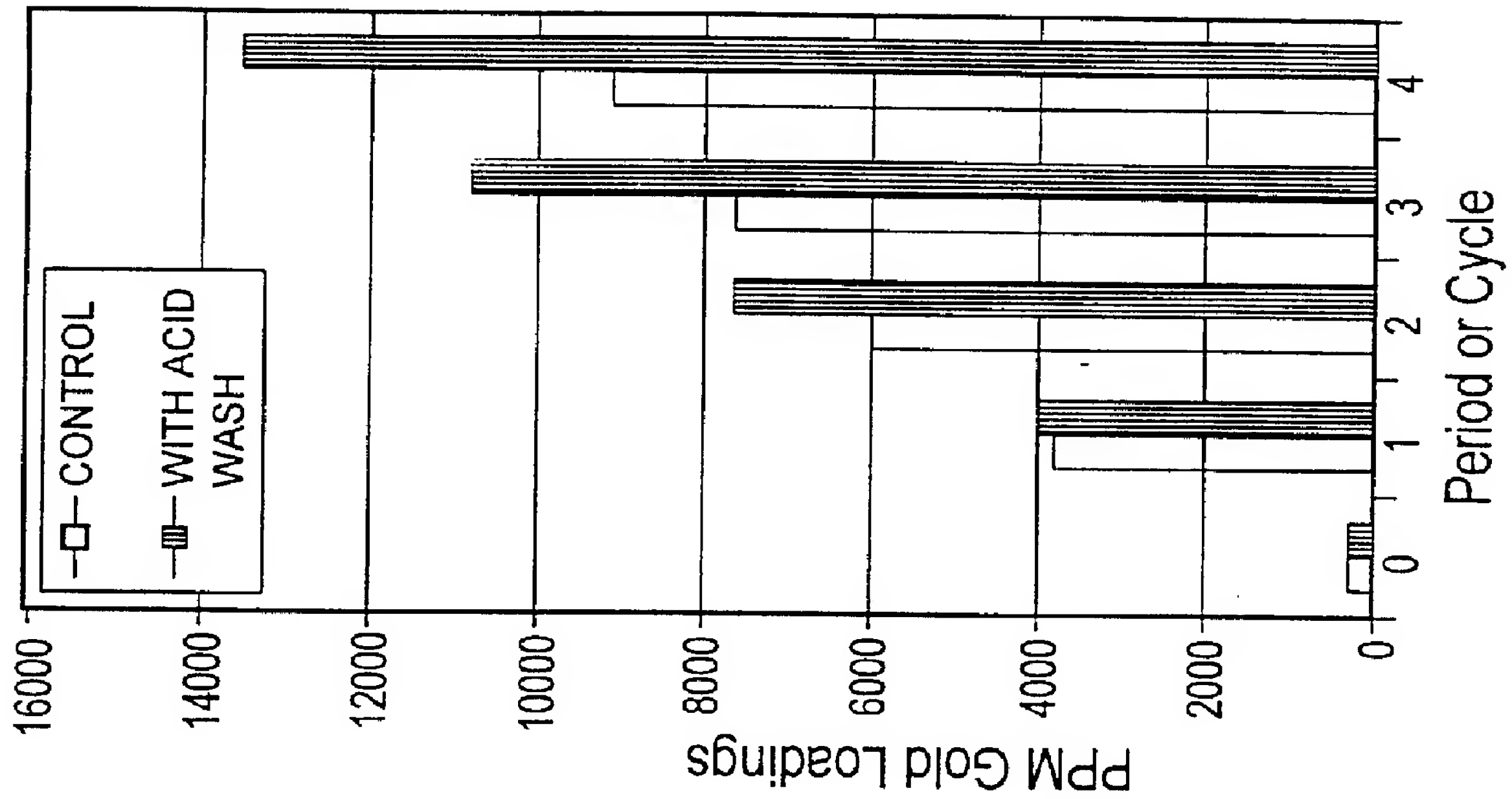


FIG. 4

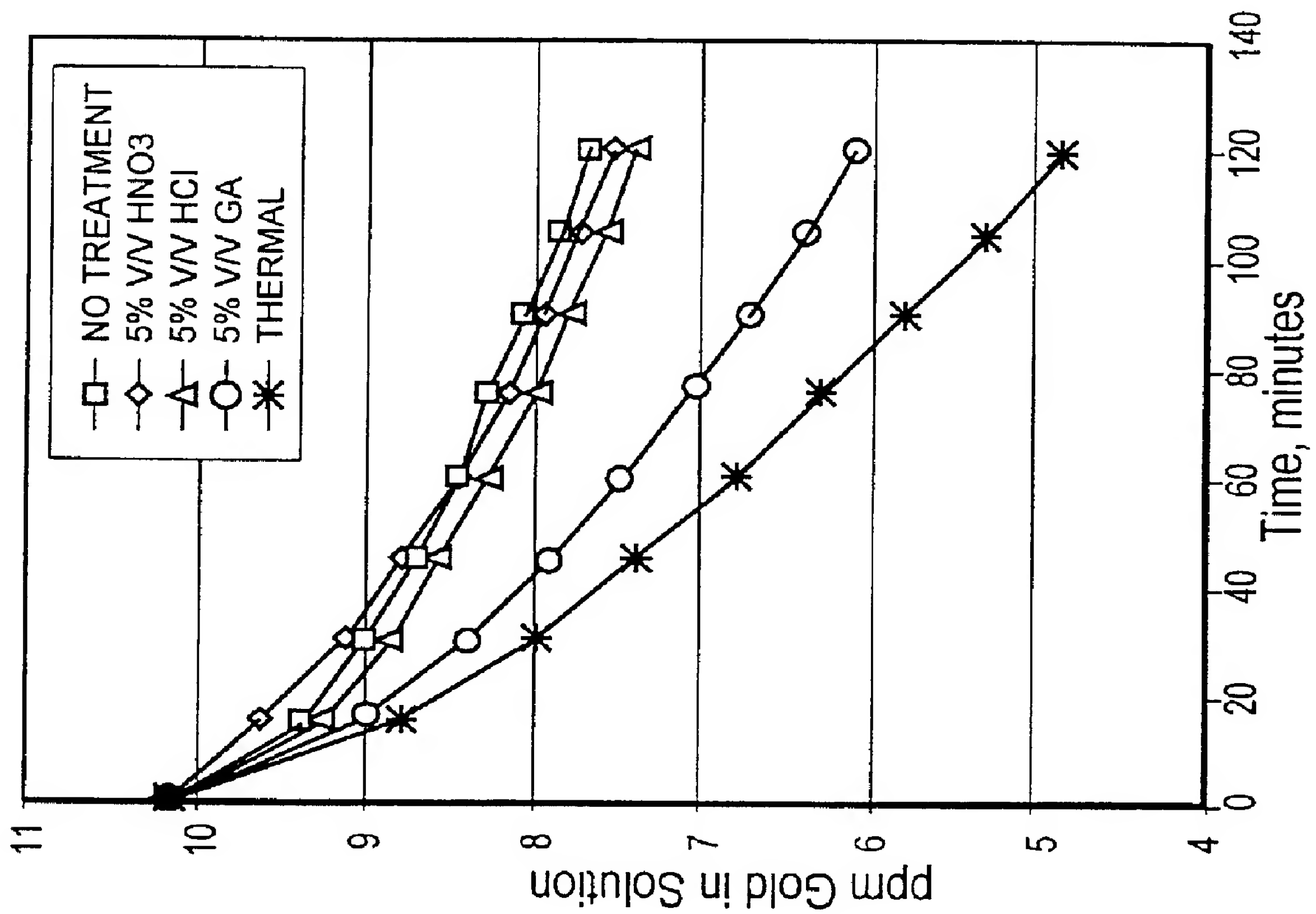


FIG. 3